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EFFECT OF AN AIR CLEANER ON THORON PROGENY

J. BIGU AND E. EDWARDSON

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EFFECT OF AN AIR CLEANER ON THORON PROGENY

J. Bigu* and E. Edwardson**

ABSTRACT

The effect of an air cleaner on ^{220}Rn progeny atmospheres has been studied in a Radon/Thoron Test Facility (RTTF) of the walk-in type. The air cleaner consists basically of a fan and a special filter material sandwiched between two metal screens, to which an electric field is applied. The filter is of the polarized media type and uses fibre glass as material. The fan and filter system are housed in a metal case. Air is drawn from the back of the case by means of the fan and forced through the 'electrical' filter where removal of ^{220}Rn progeny occurs. Radon-220 progeny 'depleted' air is discharged at the top of the device. Tests were conducted in $^{220}Rn/^{220}Rn$ progeny atmospheres when the air cleaner was operating, and when it was turned off. Very pronounced effects were observed during the operation of the device, namely: a dramatic decrease in the ^{220}Rn progeny concentrations and the total aerosol concentration, as well as a large increase in the ^{220}Rn progeny unattached fractions and the plate-out of these radionuclides on the walls of the RTTF. The air cleaner has potential in industrial applications, which should be explored.

Key words: Reduction and control of thoron progeny; Air cleaner; Electrostatic collection and deposition.

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EFFET D'UN ÉPURATEUR D'AIR SUR LES PRODUITS DE FILIATION DU THORON

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RÉSUMÉ

L'effet d'un épurateur d'air sur de l'air renfermant des produits de filiation du ^{220}Rn a été étudié dans une chambre d'essai pour le radon et le thoron (CERT) dans laquelle on peut pénétrer. L'épurateur consiste fondamentalement en un ventilateur avec un matériau filtrant spécial intercalé entre deux grillages métalliques auxquels un champ électrique est appliqué. Le filtre est constitué de fibre de verre et de type à milieu polarisé. Le ventilateur et le système filtrant sont logés dans un boitier en métal. L'air est entraîné depuis l'arrière du boitier par le ventilateur et poussé dans le filtre «électrique» où sont éliminés les produits de filiation du ^{220}Rn. L'air épuré des produits de filiation du ^{220}Rn est rejeté au sommet de l'appareil. Des essais ont été effectués avec de l'air renfermant du ^{220}Rn et des produits de filiation du ^{220}Rn lorsque l'épurateur était en marche et lorsqu'il était arrêté. Des effets très marqués ont été observés lorsque l'appareil était en marche, dont : une diminution saisissante des concentrations des produits de filiation du ^{220}Rn et de la concentration totale des aérosols ainsi qu'un accroissement considérable des fractions libres des produits de filiation du ^{220}Rn et le dépôt de ces radionucléides sur les parois de la CERT. L'épurateur offre des possibilités d'application industrielle qui devraient être explorées.

Mots clés : réduction et élimination des produits de filiation du thoron; épurateur d'air; collecte et dépôt électrostatiques.

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INTRODUCTION

There is a wide variety of airborne radionuclides in living and working environments which at sufficiently elevated concentration levels can pose a potential health hazard. A number of techniques and methods have been developed to either reduce or control airborne radioactive contamination, namely: filtration, electrostatic deposition, forced ventilation, turbulent air mixing by fans, and removal by ion-generators. These methods have been used with varying degrees of success, in laboratory experiments and real life situations, to minimize the exposure of humans to the short-lived decay products of radon (^{222}Rn) and thoron (^{220}Rn) (1-7).

A reasonable technological approach to the reduction of airborne radioactive pollutants should meet a number of important requirements such as being effective, inexpensive, and easy to use. In addition, the approach should be aesthetically acceptable, and should produce no secondary effects.

This paper describes the use of a device which operates on a 'hybrid' technique consisting of air filtration, electrostatic deposition, and turbulent air mixing to reduce the concentration levels of ^{220}Rn progeny in air. A similar study for ^{222}Rn has been reported elsewhere (8). The device (essentially an air cleaner) is potentially useful in industrial applications such as the control or abatement of radioactive and non-radioactive aerosols. This device has already been shown to be quite promising in reducing the ^{222}Rn progeny concentrations levels in certain laboratory, living and working environments (8).

DESCRIPTION OF THE DEVICE

The device, i.e., 'air cleaner' distinguishes itself by its great mechanical and electrical simplicity. It consists basically of a mixing fan and a 'polarized media' filter made up of glass fibre material sandwiched between two metal grids (screens) to which an electrical field is applied. An

electrical voltage difference of several thousand volts (V) is applied between the metal screens by means of an AC/DC converter, in conjunction with a DC voltage multiplier. The alternating current (AC) to direct current (DC) converter, converts 117 V from a conventional electrical outlet to a few V DC. The DC multiplier, in turn, converts the low voltage from the converter to a much higher signal to match the needs of the electrical polarized media filter, i.e., several thousand volts.

The fan and the grids/filter system are housed in a metal case. Air is drawn by means of the fan from the back of the device through the 'electrified' filter and then exhausted at the top of the case. The fan can be operated at three different speeds. Figures 1 and 2 show the device, which is known under the commercial name 'Electronic Air Cleaner' model CBB 1000, manufactured by CIMATEC Engineering Inc., Ottawa (Canada).

EXPERIMENTAL PROCEDURE

The device, i.e., air cleaner, was tested in a Radon/Thoron Test Facility (RTTF) of the walk-in type (9,10). Tests were conducted in $^{220}Rn/^{220}Rn$ progeny atmospheres.

The effect of the device on the following variables was investigated:

1. Radon-220 progeny Potential Alpha Energy Concentration, i.e., PAEC(Tn), as well as $[^{212}Bi]$, $[^{212}Pb]$, and the disequilibrium ratio $[^{212}Bi]/[^{212}Pb]$. The above variables were determined by a method developed by the author (11). (Note: square brackets are used here to indicate activity concentration. The symbol Tn is used to denote ^{220}Rn progeny.)
2. Radon-220 progeny plate-out on large surfaces such as the walls of the RTTF (filter substrates were used for plate-out experiments).
3. Radon-220 progeny unattached fractions.
4. Total aerosol concentration, N, and aerosol size distribution. (It should be noted that the term 'total aerosol' is used here to take into account

the contribution (to the total) from both aerosol species, namely: radioactive and non-radioactive aerosols.)

Experiments were conducted at low aerosol concentrations ($N < 1.0 \times 10^3$ cm^{-3}) and at moderate concentrations ($1.0 \times 10^4 < N < 3.0 \times 10^4$ cm^{-3}).

The effect of the air cleaner on items 1) to 4) was investigated when the device was turned off, and when the device was operated according to the following operation schedules.

1. fan on with the filter removed;
2. fan on with filter in place but no electric field applied to it;
3. fan on and the electrified filter in place; i.e., electric field applied to the filter; and
4. items 2) and 3) were repeated for several fan speeds.

In addition to the above tests, the β-particle activity corresponding to airborne ^{212}Pb and ^{212}Bi was monitored throughout the tests using a β-particle probe of the pancake type (Model HP-260, manufactured by Eberline, U.S.A.), in conjunction with its associated electronic circuitry and data acquisition/processing system (12). Finally, temperature (T) and relative humidity (RH) were carefully noted during each experiment.

EXPERIMENTAL EQUIPMENT

Dry ^{228}Th sources of the flow through type (Model Tn-1025, manufactured by Pylon Electronic Development, Ottawa, Canada), were used to produce $^{220}Rn/^{220}Rn$ progeny atmospheres in the Radon/Thoron Test Facility (RTTF). Aerosols were injected into the RTTF using aqueous solutions of uranin in conjunction with an aerosol atomizer, and associated air supply system (Model 3076 manufactured by Thermal Systems Incorporated (TSI), U.S.A). Aerosol concentration and aerosol size distribution were measured by means of a condensation nuclei counter (CNC, model 3020) and a Differential Mobility Particle Sizer (DMPS, model 3071). Both, the CNC and the DMPS were

manufactured by TSI (U.S.A.). The aerosols were injected to provide a substratum to the ^{220}Rn progeny in order to minimize their plate-out on large surfaces.

Aerosols (uranin) and ^{220}Rn were premixed in a special chamber before being injected into the RTTF through the air injection distribution system.

Unattached ^{220}Rn progeny fractions were determined using the mesh-method (13-15), according to procedures indicated elsewhere (16,17), and specially designed screen-filter/filter holder systems of the open face type.

EXPERIMENTAL RESULTS AND DISCUSSION

The experimental data obtained during the air cleaner tests have been summarized in Tables 1 to 6, and Figures 3 and 4. The results of these tests have been divided into several sections and discussed separately, as shown below.

A. EFFECT OF THE AIR CLEANER ON ^{220}Rn PROGENY

The air cleaner had a very marked effect on the concentrations of the short-lived decay products of ^{220}Rn, namely, $[^{212}Bi]$ and $[^{212}Pb]$, and hence the PAEC(Tn). (It should be noted that the square brackets are used here to indicate activity concentration, e.g., Bqm^{-3}).

Tables 1 to 3 show the effect of the air cleaner on the ^{220}Rn progeny concentrations when the device is operated under different experimental conditions. Table 1 shows data for several days of testing, whereas Table 2 shows the average effect on ^{220}Rn progeny for about 2 weeks of daily testing.

Taking airborne ^{220}Rn progeny concentration data when the air cleaner was not operated as the reference point, Table 3 shows the reduction in $[^{212}Bi]$, $[^{212}Pb]$, PAEC(Tn), and $[^{212}Bi]/[^{212}Pb]$ for several operational conditions of the air cleaner. The Table shows a slight, although significant, reduction (~10%) in the above variables when the air cleaner was operated without the electrified filter, i.e., only the fan (at medium speed)

was operated. This reduction is due to plate-out of ^{220}Rn progeny on the blades of the fan as well as to the plate-out of these radionuclides on the RTTF walls, and other nearby large surfaces, caused (or significantly enhanced) by the air turbulence produced by the operation of the device's fan. The plate-out of ^{220}Rn progeny by a mixing fan has been investigated by several researchers (2,4,5). Work on ^{220}Rn progeny has been reported by the author elsewhere (18).

A very substantial reduction in ^{220}Rn progeny ($\gtrsim$70%) was further brought about when the filter in the device was installed again, although no electrical charge was applied to it. This further reduction in the airborne ^{220}Rn progeny concentration is partly ascribed to the direct action of the filter, i.e., filtration, and partly to plate-out of the radionuclides on the fibers of the filter, an effect which is markedly enhanced by the turbulent air mixing action of the device's fan.

A dramatic (further) reduction in the airborne ^{220}Rn progeny concentration ($\gtrsim$96%) (relative to the case where the air cleaner is off) was observed when the filter was 'electrified', i.e., when an electrical charge was applied to it. The dramatic effects shown here are similar in magnitude to those found for ^{222}Rn progeny reported by the authors elsewhere (8).

Tables 1 to 3 also show a large decrease in the value of the important ratio $[^{212}Bi]/[^{212}Pb]$ caused by the operation of the air cleaner, i.e., from ~0.6 to <0.1. From these data, one may infer that the airborne $[^{212}Bi]$ decreases relative to $[^{212}Pb]$ when the device is operated, and that ^{212}Bi plates-out on large surfaces, e.g., the RTTF walls, more readily than ^{212}Pb. Alternatively, the effects observed may be due to selective removal of ^{212}Bi in the electrified filter (see Section D). It will be shown below that the operation of the air cleaner reduces the total aerosol concentration, say N, drastically, and in the process it substantially increases the plate-out of ^{220}Rn progeny on the RTTF walls. Similar effects to those discussed in this

section, but for ^{222}Rn progeny, have been reported previously elsewhere (8).

B. EFFECT OF THE AIR CLEANER ON THE TOTAL AEROSOL CONCENTRATION AND SIZE DISTRIBUTION

The air cleaner had a very pronounced effect on the concentration of (total) aerosol in the submicron size range found in the RTTF under our environmental conditions (~0.05 μm to $\lesssim$0.4 μm). Figure 3 and Table 4 show the effect of the air cleaner on the total aerosol concentration, say N. As with the case of ^{220}Rn progeny, the effects on N of different mechanical and/or electrical configurations of the device were studied. The reader should be aware that the study of the physical variables investigated here (e.g., ^{220}Rn progeny, total aerosol concentration, aerosol plate-out, radioactive or otherwise, and ^{220}Rn progeny unattached fractions) for each condition selected for the air cleaner was conducted in a parallel, simultaneous fashion, and not independently in a sequential manner as perhaps the outline of this communication might appear to indicate.

Table 4 shows N_R for all the air cleaner configurations investigated. In this Table, N_R represents the ratio of the aerosol concentration measured under a particular air cleaner condition (including the off condition), and the concentration when the air cleaner was not operating, i.e., off condition. The Table shows that a reduction of ~15% occurred when the air cleaner was operated with the filter removed, i.e., only the fan was operating. When the filter was inserted into the device, but no electrical charge was applied to it, the reduction in aerosol concentration was approximately 50%. Finally, when the electrical charge was applied to the filter, the reduction in N was about 93%.

Also shown in Table 4 are the quantities $PAEC(Tn)_R$ and $[^{212}Bi]_R/[^{212}Pb]_R$, reproduced from Table 3, for comparison purposes. Table 4 indicates that, qualitatively speaking, the effect of the air cleaner for the different configurations investigated on the total aerosol concentration, N,

is similar to that for ^{220}Rn progeny. This suggests that similar mechanisms of particle removal may be operative in both cases. From the quantitative standpoint, however, the Table shows significant differences between PAEC(Tn) and N, namely, the reduction brought about by the air cleaner on ^{220}Rn progeny (PAEC(Tn)) is substantially higher than for the total aerosol concentration, N. The above suggests that either additional particle removal mechanisms are operative in the case of ^{220}Rn progeny or that the existing mechanism(s), that apply equally well to radioactive and non-radioactive aerosols, are enhanced in the case of ^{220}Rn progeny by some more pronounced or different property of the radioactive particles than with non-radioactive aerosols.

Particle size and electrical charge distribution differences between the ^{220}Rn progeny atmosphere and the non-radioactive aerosol cloud, as well as differences in particle deposition velocity, are properties or characteristics of the aerosol milieux that come to mind. However, because of the experimental difficulties in discriminating radioactive from non-radioactive aerosols, and the widely different experimental techniques used to measure both aerosol species, only speculative arguments can be suggested to explain the preliminary data reported here.

In addition to the above results, a study on the size distribution of total aerosol shows that the air cleaner had an effect on the particle size distribution as evidenced by a reduction in the geometric mean of the aerosol diameter from ~0.13 μm to ~0.11 μm when the air cleaner was in operation. This effect can be interpreted as the device being slightly more efficient in removing particles below an undetermined size than in removing particles above this size 'threshold'. The effect of the air cleaner on the total aerosol distribution is shown in Figure 4.

C. EFFECT OF THE AIR CLEANER ON THE PLATE-OUT OF ^{220}Rn PROGENY ON LARGE SURFACES

Recently formed ^{220}Rn readily attach themselves to aerosols. This

results in a decrease in the diffusibility of ^{220}Rn progeny, and hence, in a decrease in the probability of plating-out on large surfaces. However, when the physical space is depleted of aerosols, the ^{220}Rn progeny find no substrata to attach to, and hence, they plate-out readily on walls and other large surfaces.

It has been shown in the previous section that the operation of the air cleaner causes a large reduction in the total aerosol concentration, N, in the RTTF. Because of this, and the argument above, one may conclude on theoretical grounds, that an increase in the ^{220}Rn progeny plated-out on the RTTF walls should occur when the air cleaner is operated as compared with the device not operating. This is indeed the case, and experimental data supporting this are given below.

As previously indicated, measurements of plate-out of ^{220}Rn progeny on the RTTF walls were conducted by measuring the α-particle activity on material substrates placed at different locations on the walls of the RTTF. Exposure (24 h) of these substrates gave the following results:

$N_\alpha(P/O)$ ($Bq\ cm^{-2}$)	N (cm^{-3})	Air Cleaner Operation
0.53 ± 0.09	2.0×10^4 - 2.8×10^4	OFF
0.73 ± 0.07	1.6×10^3 - 1.8×10^3	ON

The above data indicate that the plated-out ^{220}Rn progeny on the RTTF walls, indicated by $N_\alpha(P/O)$, increased by about 40% when the air cleaner was operated as compared with the case when the device was turned off. Under the same experimental conditions, the total aerosol concentration, N, suffered a ~15-fold reduction. The increase in 40% for the ^{220}Rn progeny plated-out on the RTTF wall represents quite a large quantity when the total surface area of the RTTF is taken into account (~60 m^2). Radioactive mass balance and continuity considerations show that the increase in plated-out activity on the

walls and other large surfaces must equal the decrease in airborne radioactivity in the RTTF volume (~30 m^3). A quick calculation shows that the loss of activity due to plate-out caused by the air cleaner under the operating experimental conditions was less than about 1.0×10^5 Bq. (It should be noted that $N_\alpha(P/O)$ was measured 10 min after removal of the substrate from the RTTF walls. This quantity varies, of course, with time after removal from the RTTF. Hence, care should be exercised when 'absolute' and precise measurements are needed as opposed to relative measurements. This discussion is, however, beyond the scope of this communication.

Table 5 shows a different set of plate-out measurements conducted with much shorter exposure times because of practical considerations. Because the air cleaner has an effect on both radioactive and non-radioactive aerosols, quantification of the effect of the device on ^{220}Rn progeny is not straightforward. Table 5 shows $N_\alpha(P/O)$ and N, but because of the interdependence between these two variables, and the effect of the air cleaner on both, a simple inspection of the two sets of values for these two physical quantities does not reveal much. A more meaningful quantity can be expressed by the ratio $N_\alpha(P/O)/N$, which gives an indication of the ^{220}Rn progeny plated-out activity as related to the aerosol concentration still airborne in the RTTF.

The useful ratio $N_\alpha(P/O)/N$ can then be related to N, or other variables. By the same token, two other useful ratios are of interest in the context of this discussion, namely, $N_\alpha(P/O)/PAEC(Tn)$ and $PAEC(Tn)/N$. The ratio $N_\alpha(P/O)/PAEC(Tn)$ is indicative of the plate-out of ^{220}Rn progeny relative to the ^{220}Rn progeny concentration still airborne in the RTTF, whereas the second ratio, namely, PAEC(Tn)/N, is another indicator of plate-out as related to total airborne aerosol concentration. The three ratios indicated above depend on N. The ratios $N_\alpha(P/O)/PAEC(Tn)$ and $N_\alpha(P/O)/N$ are inversely related to N and increase dramatically with the decrease in N caused by the operation of the air cleaner, as Table 5 shows. The ratio PAEC(Tn)/N

decreases with decreasing N, which clearly indicates a decrease in airborne ^{220}Rn progeny concentration, and hence, an increase in plated-out activity on the RTTF walls, as the total (airborne) aerosol concentration is reduced by the action of the air cleaner. As expected, the effect of the device is largest when the fan and electrified filter are operating, and smallest when only the fan is operating, i.e., filter removed.

D. EFFECT OF THE AIR CLEANER ON THE ^{220}Rn PROGENY UNATTACHED FRACTION

The unattached ^{220}Rn progeny fractions, f_u, were measured under normal experimental conditions in the RTTF, i.e., when the air cleaner was not operating, and during operation of the device. The results obtained for ^{212}Bi, ^{212}Pb and PAEC(Tn) are shown in Table 6.

As previously discussed, ^{220}Rn progeny plates-out on large surfaces such as vessel walls, and other large surfaces. The plate-out of ^{220}Rn progeny is very dependent on aerosol concentration and aerosol size distribution. The ^{220}Rn progeny fraction that plates-out more readily is the so-called 'unattached fraction, f_u, i.e., ^{220}Rn progeny that do not 'combine' or attach to other aerosols either because of aerosol size distribution considerations, or because of the absence of aerosols, or insufficient aerosol concentration. Furthermore, because the air cleaner has proved to be quite efficient in removing aerosols from air, operation of this device is expected to have a significant influence on both plate-out mechanisms and on its direct 'precursor', the unattached ^{220}Rn progeny fractions.

Table 6 shows the unattached fraction corresponding to ^{212}Pb, ^{212}Bi, and PAEC(Tn) measured in the RTTF for several operating conditions of the air cleaner. The unattached fractions, denoted by the symbol f_u, in Table 6 are given in percentages. The Table shows that under normal conditions, i.e., air cleaner off, the unattached fractions were quite small (~0.5%), whereas when the device was turned on, f_u increased considerably, i.e., up to 27% for ^{212}Pb

and PAEC(Tn). This behaviour is consistent with the drastic reduction in total aerosol concentration caused by the operation of the air cleaner, i.e., the unattached fraction increases with decreasing aerosol concentration, and vice versa.

As indicated in a previous section, aerosols serve as substrata for the attachment of ^{220}Rn progeny. In this 'attached' form, the diffusibility of the resulting radioactive aerosols in air is reduced, and hence, their probability of being removed by plate-out mechanisms on large surfaces is greatly reduced. The reverse argument is equally applicable.

Table 6 indicates that the f_u values for ^{212}Pb and PAEC(Tn) are essentially the same. This result is to be expected because the contribution from ^{212}Pb to (the calculation of) PAEC(Tn) is, depending on the ratio $[^{212}Bi]/[^{212}Pb]$, approximately equal or greater than 90%. As expected from the discussion above, the unattached fractions are lowest when the air cleaner is off increasing slightly when the filter is in place, but no charge is applied to it, finally increasing dramatically when the filter is electrified, i.e., electrical charge is applied to it.

It should be noted that although values for f_u (^{212}Bi) are also given in Table 6, these values are not accurate because an empirically determined correction factor used in the calculation of f_u (16,17) could only be calculated with a large error. The reason for this lies in the low activities measured on the screens, and hence, the small difference in activities measured between the back-up filter of the f_u-measuring device and a reference filter placed side by side according to procedures outlined elsewhere (16,17).

In a previous section, the decrease of the ratio $[^{212}Bi]/[^{212}Pb]$ with the operation of the air cleaner was attributed to selective plate-out of ^{212}Bi on the RTTF walls. If this theory is correct then one would expect the following inequality to hold, namely: $f_u(^{212}Bi) > f_u(^{212}Pb)$. This is not the case according to the data in Table 6. However, because of the large errors

associated with the calculation of the correction factor alluded to above, it is not clear that the above inequality holds true. If selective plate-out is not the mechanism accountable for the observed effects (see section C), then the decrease in the value of the ratio $[^{212}Bi]/[^{212}Pb]$ with the operation of the air cleaner can tentatively be ascribed to selective deposition or removal of ^{212}Bi in the electrified filter. It is clear that more work will be necessary to clarify this point. A study similar to the one presented here, but for ^{222}Rn progeny, concluded that variation in the ^{222}Rn progeny disequilibrium ratios was most probably due to selective plate-out of these radionuclides on the RTTF walls (8). In view of the data reported in this section, this conclusion may have to be modified and the possibility of selective removal of ^{222}Rn progeny by the electrified filter should be further investigated.

CONCLUSIONS

The operation of the air cleaner had a dramatic effect on the ^{220}Rn progeny concentrations and the ^{220}Rn progeny disequilibrium ratio $[^{212}Bi]/[^{212}Pb]$, as well as on the ^{220}Rn progeny unattached fractions, the plate-out of ^{220}Rn progeny on the RTTF walls and the total aerosol concentration. Some small effect (~10%) on the total aerosol size distribution was also observed.

The ^{220}Rn progeny concentrations, the ratio $[^{212}Bi]/[^{212}Pb]$ and the total aerosol concentration were greatly reduced, whereas the unattached fractions and the plate-out of ^{220}Rn progeny on the RTTF walls were greatly increased by the operation of the air cleaner. The above effects are interrelated as discussed above. The magnitude of the effects observed varied with the operation of the air cleaner, namely: off; only fan operating with the filter removed; fan operating, filter in place but no electrical charge applied to it; and finally fan and electrified filter (i.e., filter with

electric charge applied to it) operating. Maximum effects were obtained with the last air cleaner configuration.

There is a great potential for this type of air cleaner in industrial applications as well as for living environments to control and/or reduce ^{220}Rn progeny and total aerosol concentration. The device is also of interest for research purposes enabling the user to alter the ^{220}Rn progeny disequilibrium ratio. The device could easily be adopted by, and adapted to, the mining industry for air quality control purposes.

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Table 1 - Effect of the air cleaner on ^{220}Rn progeny in the RTTF

Date 1990	$[^{212}Pb]$ (Bqm^{-3})	$[^{212}Bi]$ (Bqm^{-3})	$\frac{[^{212}Bi]}{[^{212}Pb]}$	PAEC(Tn) (μJm^{-3})	Air Cleaner* Remarks
Oct. 17	6000.4	3452.3	0.57	440.1	OFF
"	200.9	22.0	0.11	14.1	ON
Oct. 18	220.0	20.5	0.09	15.4	ON
"	5067.0	2451.1	0.48	368.4	OFF
Oct. 23	6485.0	3723.6	0.57	475.6	OFF
"	5152.5	2757.7	0.53	376.5	ON (No filter, no charge)
Oct. 24	1811.7	559.5	0.31	129.4	ON (Filter, no charge)
"	275.4	26.6	0.10	19.3	ON
Oct. 30	5951.1	3273.0	0.55	435.4	OFF
Oct. 31	201.9	16.8	0.08	14.1	ON

*When the air cleaner was operated, the fan was set at medium speed.

Table 2 - Average effect of the air cleaner on ^{220}Rn progeny in the RTTF

$[^{212}Pb]$ (Bqm^{-3})	$[^{212}Bi]$ (Bqm^{-3})	$\frac{[^{212}Bi]}{[^{212}Pb]}$	PAEC(Tn) (μJm^{-3})	Air Cleaner Remarks
5876	3225	0.55	430	OFF
5152	2758	0.53	376	ON (No filter, no charge, only fan on)
1812	559	0.31	129	ON (Filter, no charge on)
224	21.5	0.10	15.7	ON*

*Indicates fan on (medium speed), filter installed and electrical charge applied to the filter.

Table 3 - Airborne ^{220}Rn progeny reduction caused by the operation of the air cleaner.

$[^{212}Pb]_R$	$[^{212}Bi]_R$	$\frac{[^{212}Bi]_R}{[^{212}Pb]_R}$	$PAEC(Tn)_R$	Air Cleaner Remarks
1	1	1	1	OFF
0.88	0.86	0.96	0.87	ON (No filter, no charge, fan only)
0.31	0.17	0.56	0.30	ON (Filter, no charge)
0.038	0.0067	0.18	0.036	ON*

*Indicates fan on (medium speed), filter installed, and electrical charge applied to the filter.

Note: The above quantities (subindexed with an R) represent the ratio of the values obtained for a particular air cleaner setting (including off) and the values obtained when the air cleaner is not operating.

Table 4 - Reduction of total aerosol concentration caused by the operation of the air cleaner.

N_R**	$PAEC(Tn)_R^+$	$\frac{[^{212}Bi]_R^{++}}{[^{212}Pb]_R}$	Air Cleaner Remarks
1.0	1.0	1.0	OFF
0.85	0.87	0.96 (No filter, no charge, fan only)	ON
0.54	0.30	0.56 (Filter, no charge)	ON
0.068	0.036	0.18	ON*

*Indicates fan on (medium speed), filter installed, and electrical charge applied to the filter.

**Represents the ratio of aerosol concentration measured under a particular air cleaner setting (including off) and the concentration obtained when the air cleaner is not operating.

$^{+}$,$^{++}$For an explanation of $PAEC(Tn)_R$ and $[^{212}Bi]_R/[^{212}Pb]_R$ refer to Table 3.

Table 5 - Effect of the air cleaner on ^{220}Rn progeny plate-out on the RTTF walls, and other data of interest.

Date 1990	Air Cleaner (Remarks)	$N_\alpha(P/O)$ (Bqm^{-2})	$\frac{PAEC(Tn)}{N} \times 10^6$ (μJ)	N (cm^{-3})	$\frac{N_\alpha(P/O)}{PAEC(Tn)}$ ($Bq\ \mu J^{-1} m^{-1}$)	$\frac{N_\alpha(P/O)}{N} \times 10^6$ (Bqm^{-4})
Oct. 23	OFF	1429±170	0.021	22,500	3.00	0.063
"	ON*	1531±238	0.021	17,800	4.07	0.086
Oct. 24	ON+	714±136	0.015	8,300	5.53	0.086
"	ON++	1326±204	0.013	1,475	68.70	0.899

*Fan on, no filter, no charge on filter.

+Fan on, filter, no charge on filter.

++Fan on, filter, charge on filter.

Notes: 1) The fan was operated with the fan running at medium speed.

2) N stands for total aerosol concentration.

Table 6 - Radon-220 progeny unattached fractions

Date (1990)	f_u(PAEC(Tn)) (%)	f_u(^{212}Pb) (%)	f_u(^{212}Bi) (%)	Air Cleaner Remarks
Oct. 17	0.5	0.5	0.7	OFF
"	27.0	27.0	16.0	ON*
Oct. 18	21.0	21.0	11.0	ON*
"	0.5	0.5	0.6	OFF
Oct. 23	0.4	0.4	0.5	OFF
"	0.5	0.5	0.6 (No filter, no charge)	ON
Oct. 24	1.3	1.3	1.1 (Filter, no charge)	ON
"	18.0	18.0	1.8(?)	ON*

*Indicates fan on (medium speed), filter installed, and electrical charges applied to filter.

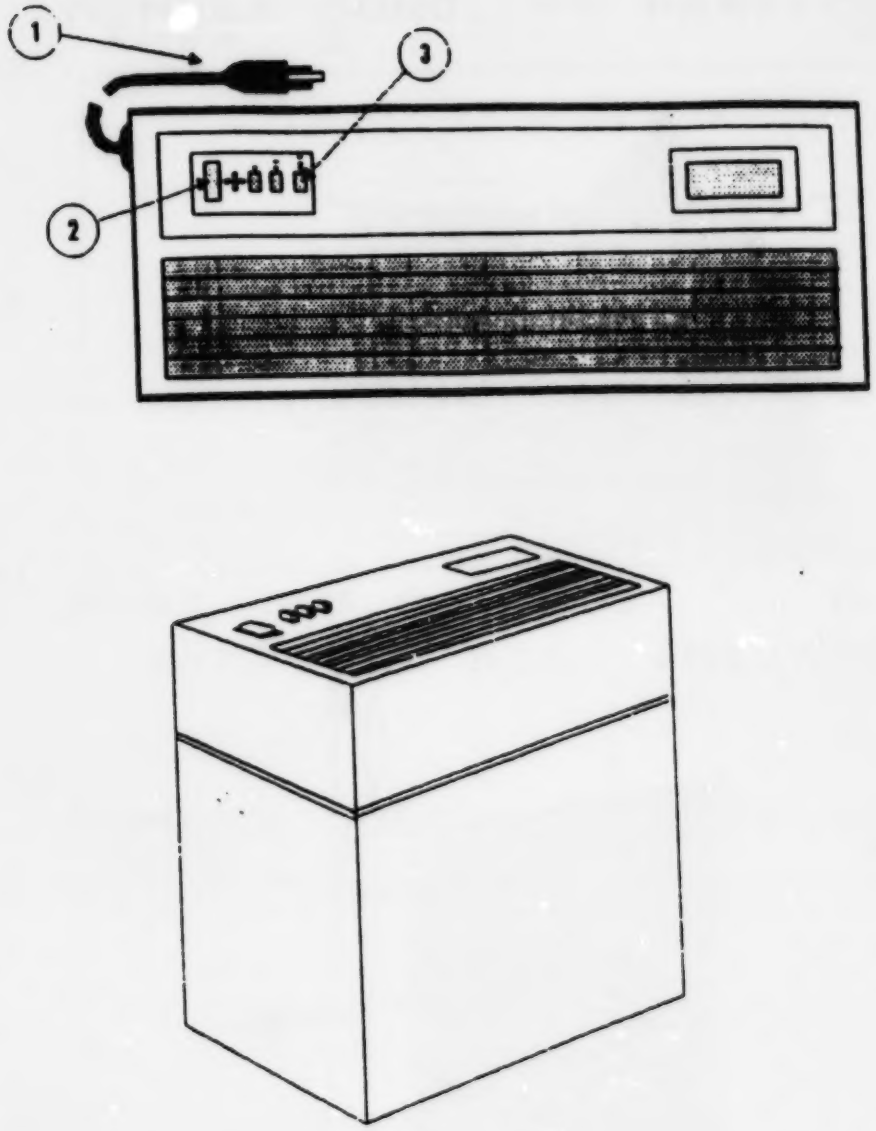

Fig. 1 - Air cleaner: top view (upper drawing), and side view (lower drawing).

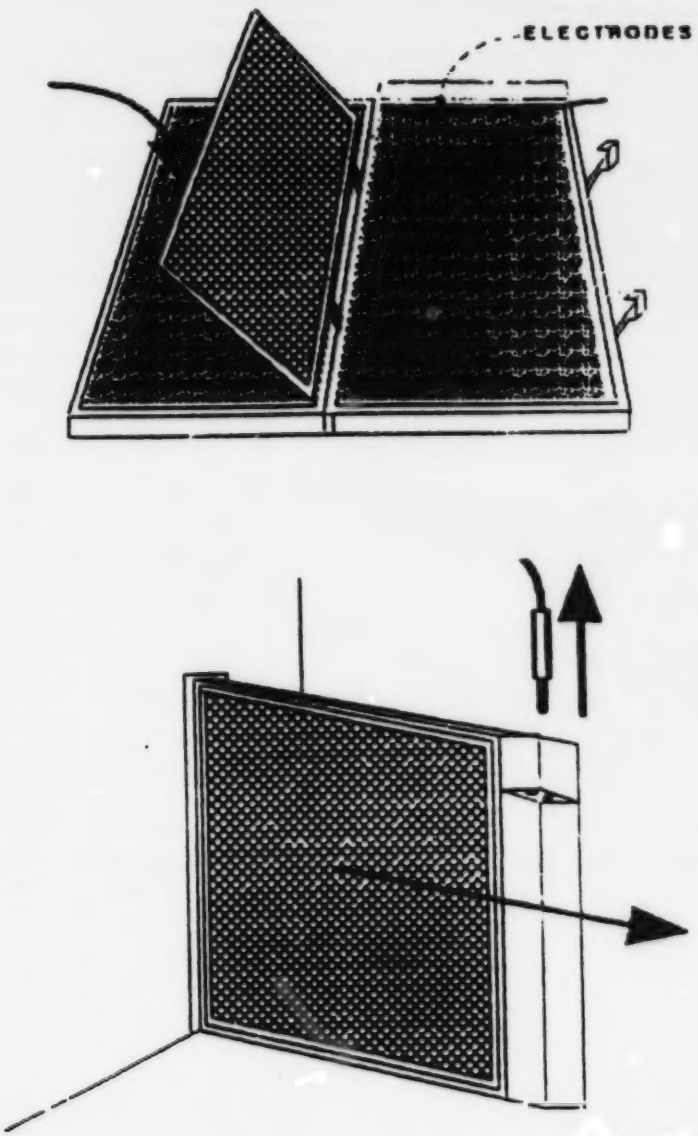

Fig. 2 - Details of the filter/screens system: screens open (upper drawing), and system mounted ready to be installed in the metal case of the air cleaner (lower drawing).

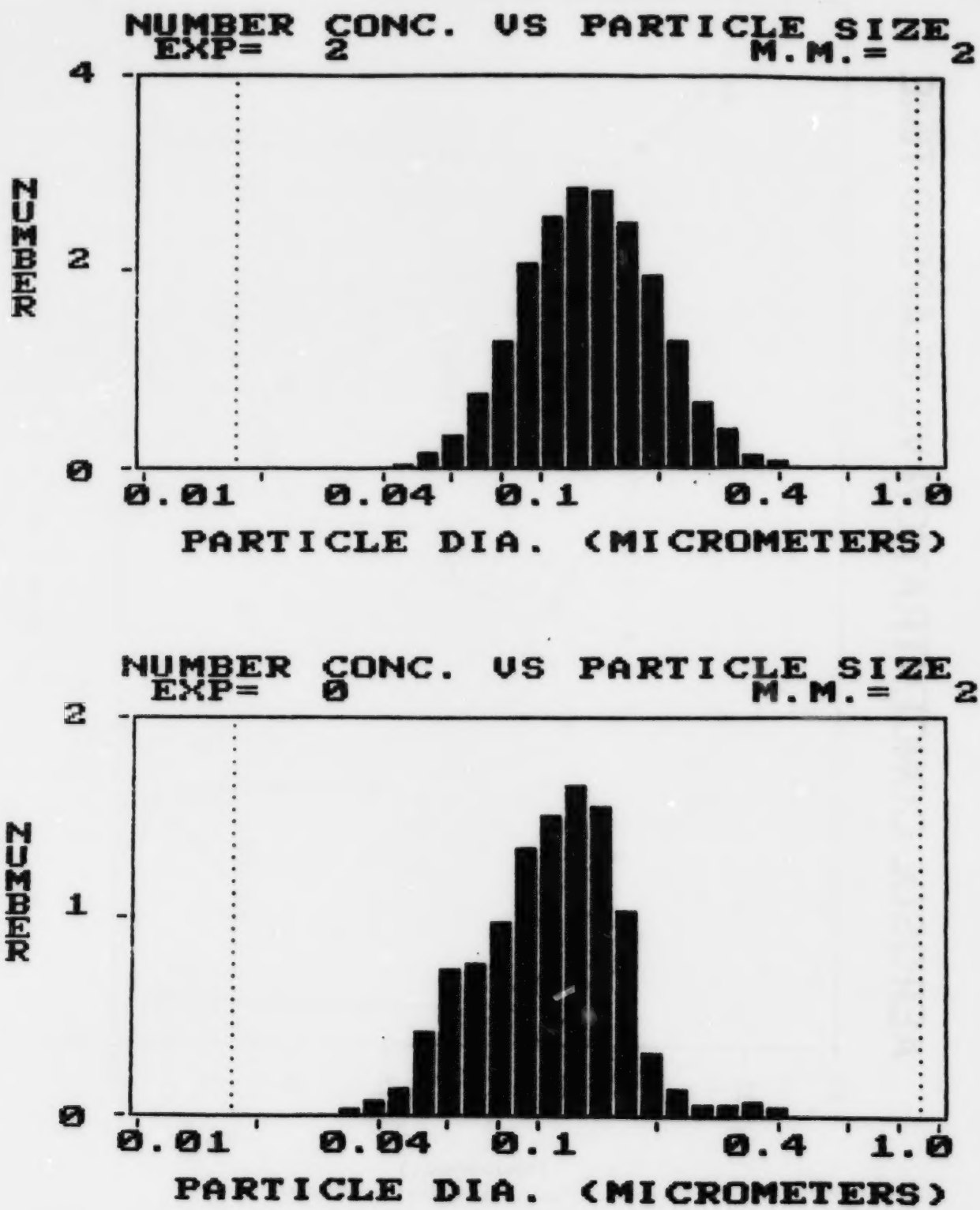

Fig. 3 - Aerosol size distribution in the RTTF when the air cleaner is not operating (upper graph), and during operation of the device.

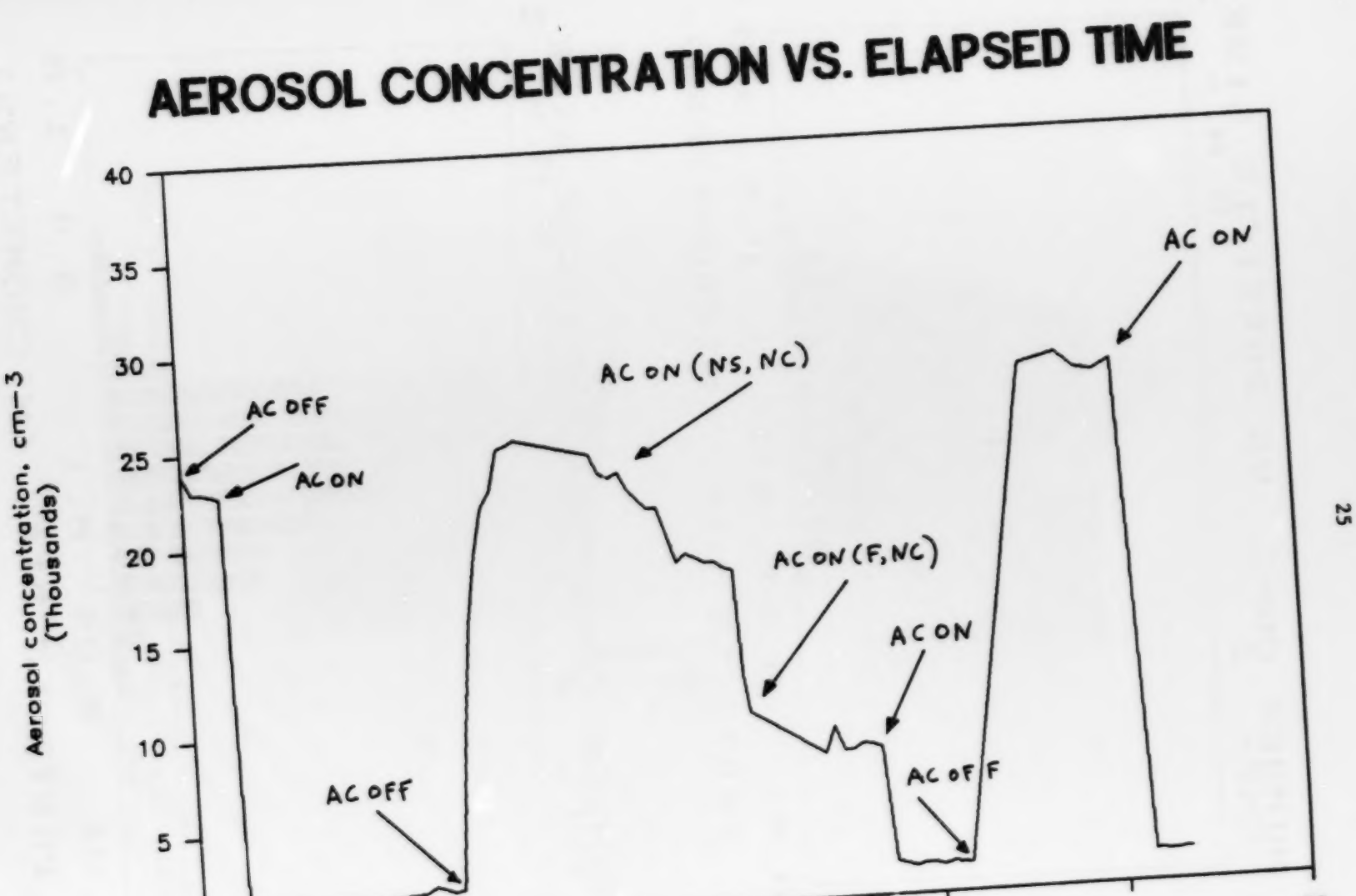

Fig. 4 - Effect of the air cleaner (AC), on the total aerosol concentration (N). The abbreviations NS, NC and F stand for no screen, no charge, and filter in place, respectively.